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Spatiotemporal Variability in Hydrological Drought Recovery Time Estimations from GRACE and GRACE-FO Data

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This study aimed to explore the global spatiotemporal variability in hydrological drought recovery time (DRT) estimated using terrestrial water storage (TWS) and station-based precipitation data. TWS data were gathered from the Gravity Recovery and Climate Experiment (GRACE) between April 2002 and June 2017 and GRACE Follow-On (GRACE-FO) between June 2018 and September 2023. The GRACE and GRACE-FO mascon (RL06) solution were used. Precipitation data were obtained from the Global Precipitation Climatology Project (GPCP) monthly analysis product. DRT was derived from the following two approaches: (1) TWS data via storage deficit and (2) TWS and precipitation data via absolute required precipitation. Storage deficit was computed as the negative deviation of detrended TWS from climatological values. Absolute required precipitation to fill the storage deficit was estimated from the linear relationship between the cumulative detrended smoothed precipitation anomalies (cdPA) and detrended smoothed TWS anomalies (dTWSA). The end of hydrological drought was assumed as when TWS deviation turned positive for the first methodology and as when observed precipitation exceeded absolute required precipitation for the second one. Mean DRT values across continents were obtained for both the GRACE and GRACE-FO periods, and the temporal variability between these periods was explored across different continents. On average, DRT estimate was 29% higher during the GRACE period (11.2 months) than during the GRACE-FO period (8.6 months). The TWS-based method (11.5 months) yielded 38% higher DRT than did the TWS- and precipitation-based one (8.3 months). Overall, Australia exhibited the highest DRT estimate (averaging 11.3 months) among all continents for both methods, whereas Europe showed the lowest one (averaging 8.6 months), with a global average of 9.9 months. Analysis of the temporal consistency between DRT estimates from both methods revealed that 28% of estimates aligned during the GRACE period, increasing to 49%

during the GRACE-FO period. In particular, the highest consistency (61%) was observed over Africa during GRACE-FO period, contrasting with the lowest consistency (17%) over Australia during the GRACE period. Overall, the consistency between the DRT estimates from the two methods increased from the GRACE period to the GRACE-FO period across all the continents by 18% to 40%, except for Europe, where consistency dropped by 3%. These findings provide insights not only into the potential of TWS data in globally estimating DRT with significant consistency but also into understanding the dynamics of global hydrological droughts, thus proving beneficial in devising management strategies for water resources.